Microalgae Biomass for Biodesel: Reality and Prospectives

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Yes we can !!!

Assuming we will do the right things

Solve the real problems

Not create new ones

- Nutrient efficiency utilization
- Pond / Culture management
- Develop systems with multiple product utilization
- Avoid the use of limited resources

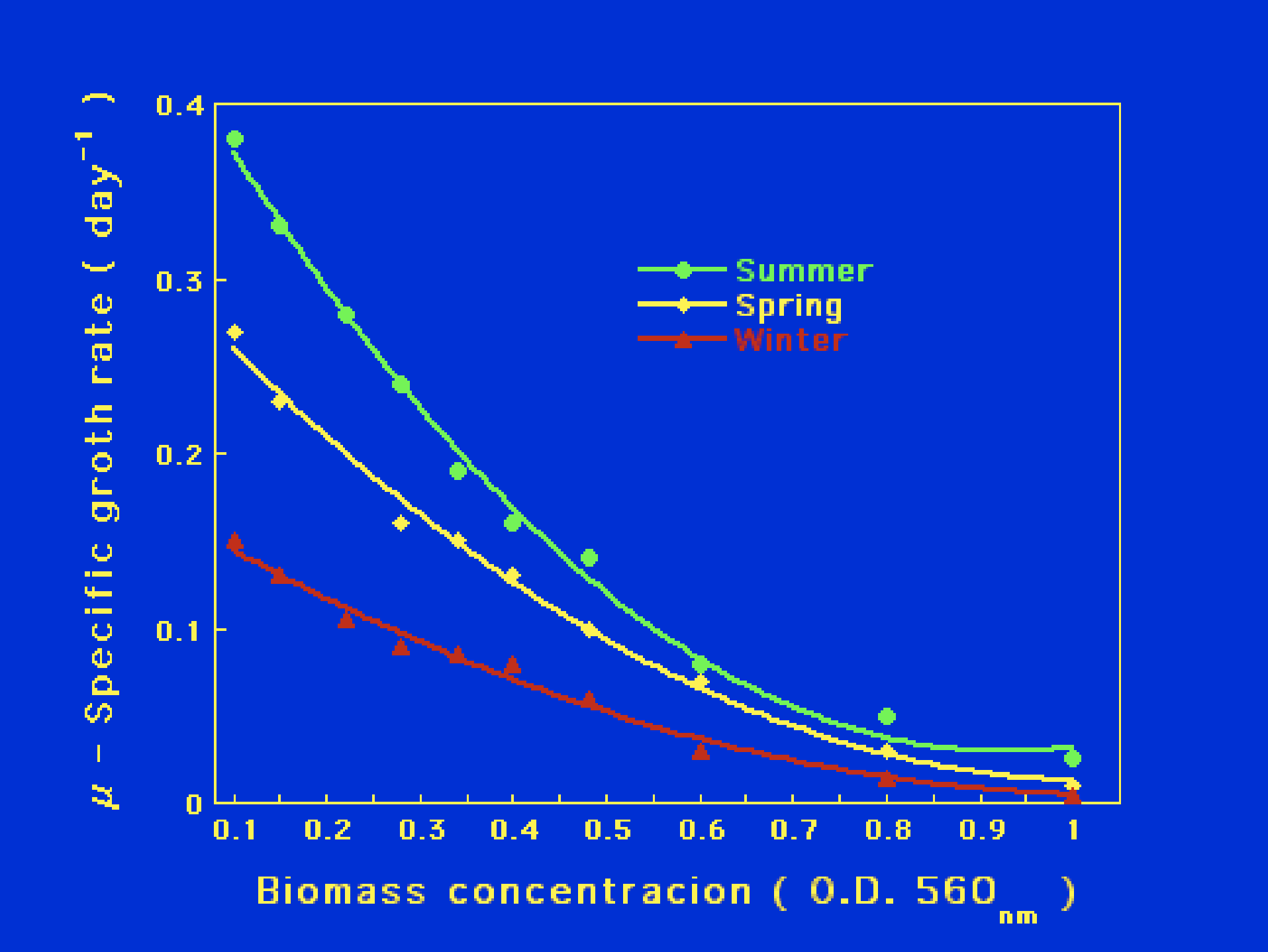
Fact and Fictions

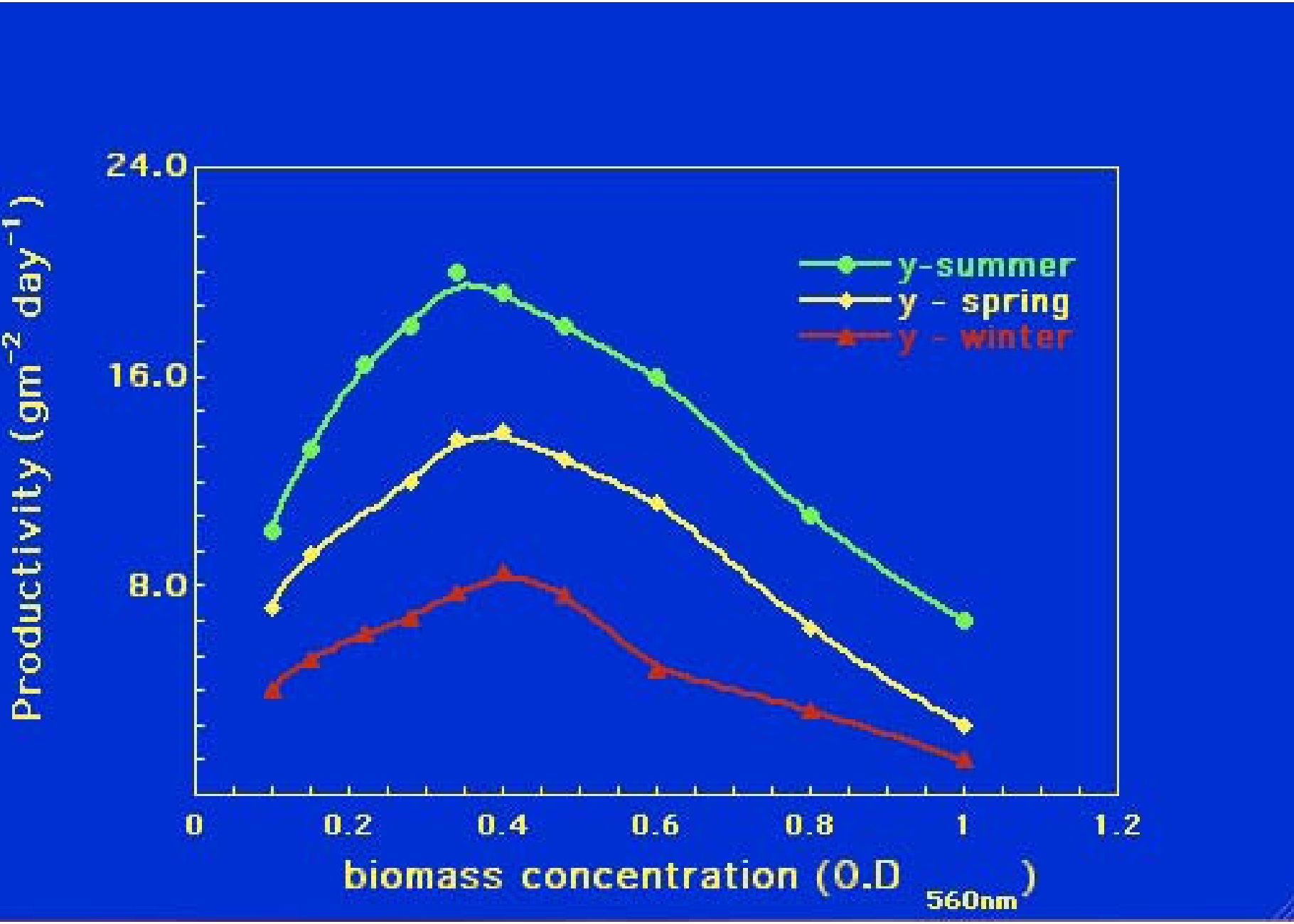
- "…Algae are the fastest-growing organisms on the planet…." NOT TRUE
- (E. coli doubling time of 20 min)
- So what is TRUE?
- Some micro algae species have a very fast specific growth rate (μ) as compared to other photosynthetic organisms.
- (Some Cyanobacteria have a Doubling time of 180 min)
- The highest productivity is not achieved at the fastest growth rates

$$\mathbf{Y = \mu \cdot X}$$

Specific growth rate – μ

Biomass concentration - X


μ - Specific groth rate (day-1)
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Summer
Spring
Winter
Biomass concentracion (O.D. 560nm)


24.0
16.0
8.0
Productivity (gm^{-2} day^{-1})
y-summer
y - spring
y - winter
0
0.2
0.4
0.6
0.8
1
1.2
biomass concentration (O.D $_{560nm}$)

The Fiction of Microalgae Biodisel

Oil yields	liters/ha-yr	barrels/ha-yr
Soybeans	400	2.5
Sunflower	800	5
Canola	1,600	10
Jathropha	2,000	12
Palm Oil	6,000	36
Microalgae	60,000-240,000*	360 -1500*

*Projected high yield is ~2 x theoretical efficiency!

The 7th European Workshop "Biotechnology of Microalgae" June 11, 2007

Isaac Berzin, GreenFuel Technologies

- High productivity per unit area (g/m^2-day)
- Harvested daily, reducing inventory and logistics
- Do not need arable land
- Do not need potable water
- Able to de-link food/fuel competition
- Tremendous natural variability; over 20,000 species

Crop	Annual Oil Yield liter/ha
Corn	120
Soy	440
Safflower	780
Sunflower	950
Castor	1400
Rapeseed	1600
Jatropha	1800
Jojoba	1800
Coconut	2700
Palm	6000
Algae	15,000-80,000

Yield of Various Plant Oils

Crop	Oil in Liters per hectare
Castor	1413
Sunflower	952
Safflower	779
Palm	5950
Soy	446
Coconut	2689
Algae	***100000***

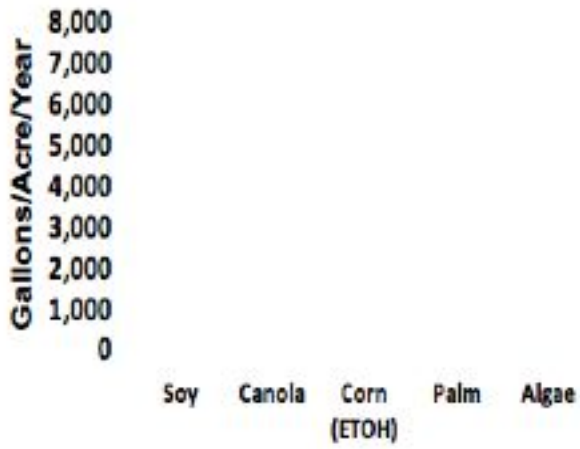
From a Solix presentation

Land & Water Efficiency

SOLIX

Annual Production

- Soybean: 40 to 50 gal/acre
- Rapeseed: 110-145 gal/acre
- Mustard: 140 gal/acre
- Jatropha: 175 gal/acre
- Palm oil: 650 gal/acre
- Algae est.: 5,000-10,000 gal/acre
  7,000 "nominal"



ExxonMobil Launches Major Advanced Algal Biofuel Research and Development Program With Synthetic Genomics; More than $600M Targeted
14 July 2009

Approximate yields for other biofuel sources are far lower :

Palm: 650 gallons per acre per year

Sugar cane: 450 gallons per acre per year

Corn: 250 gallons per acre per year

Soy: 50 gallons per acre per year

EMRE estimates that algae could yield more than 2,000 gallons of fuel per acre of production per year

However, naturally-occurring algae do not carry out this process at the efficiencies or rates necessary for commercial-scale production of biofuels.

Use of unites such as:
hectares,
acres,
long tons,
short tons,
metric tons,
US gallons,
Imperial gallons
is both tiresome and tedious.

You may think **big** but please use SMALL words (unites),
what is wrong with

$$gr\ m^{-2}\ day^{-1}$$

Trying to compare and evaluate productivity

Based on the best productivity obtained in large scale production facilities. Annual productivity of BIOMASS

- 15- 20 gr m^{-2} day^{-1} and operation of 300 days per year
- 45 - 60 ton /ha/year or 11 -15 ton/Acre/year

Oil production - Based on 30% content in a none stressed culture and 100% efficiency of extraction.

- 20,000 lit / Ha / year
- 6000 gal /Ha / year
- 2400 gal / Acre /year

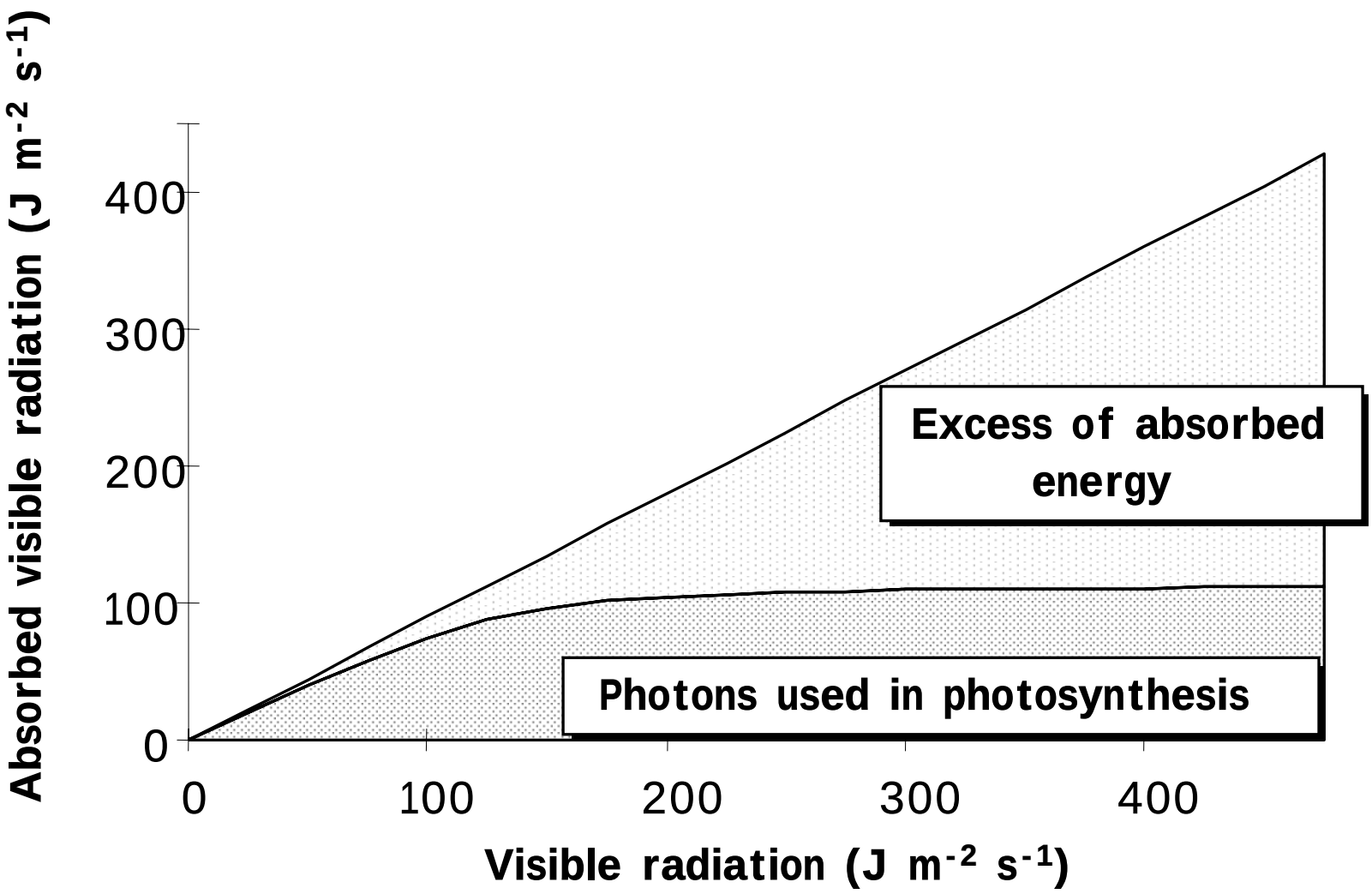
But we have to remember that even those numbers are yet to achieved in large scale facilities

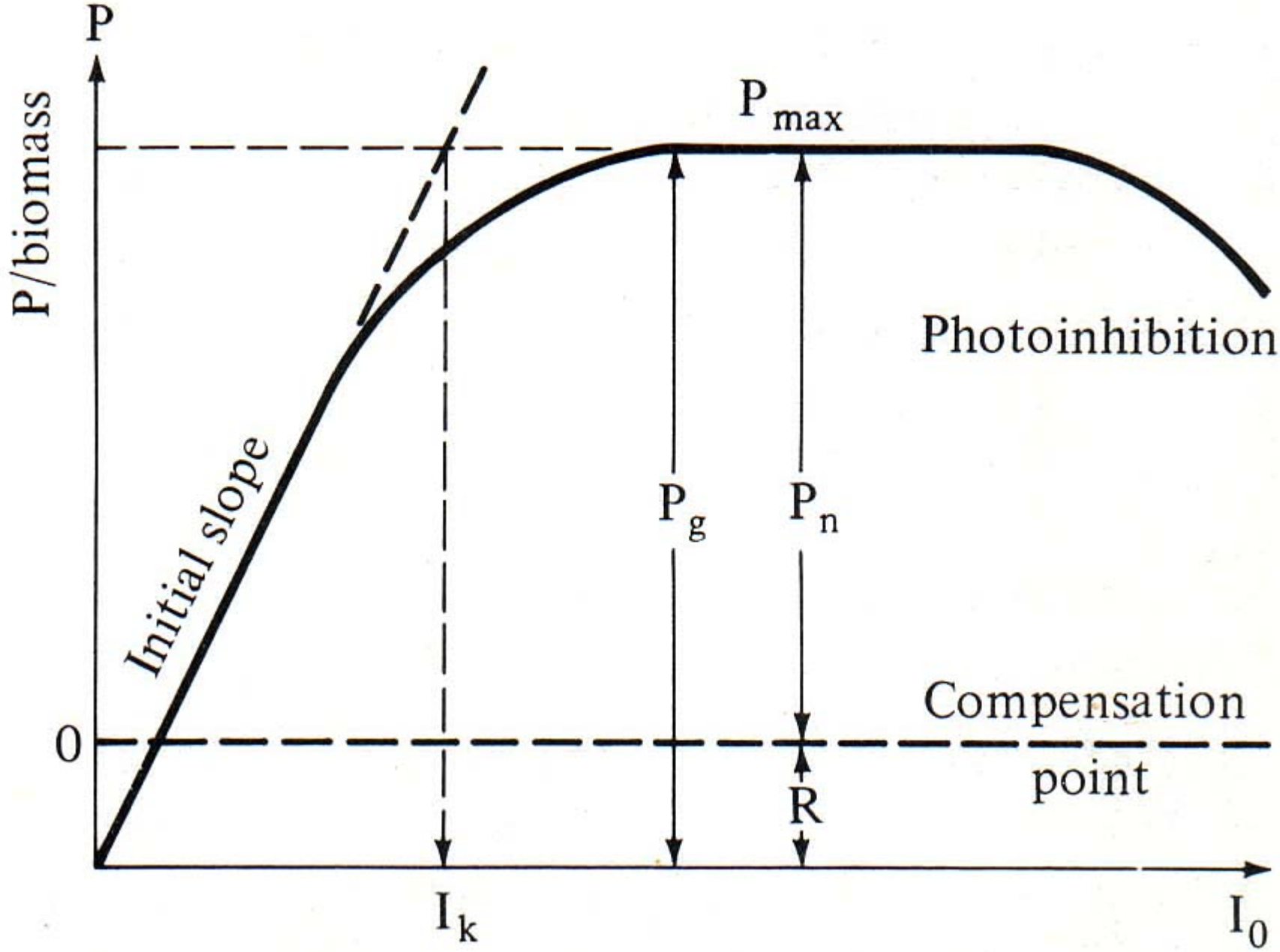
"….Algae are finely tuned biological factories, specialized to convert sunlight into biomass more efficiently than any other life form.."

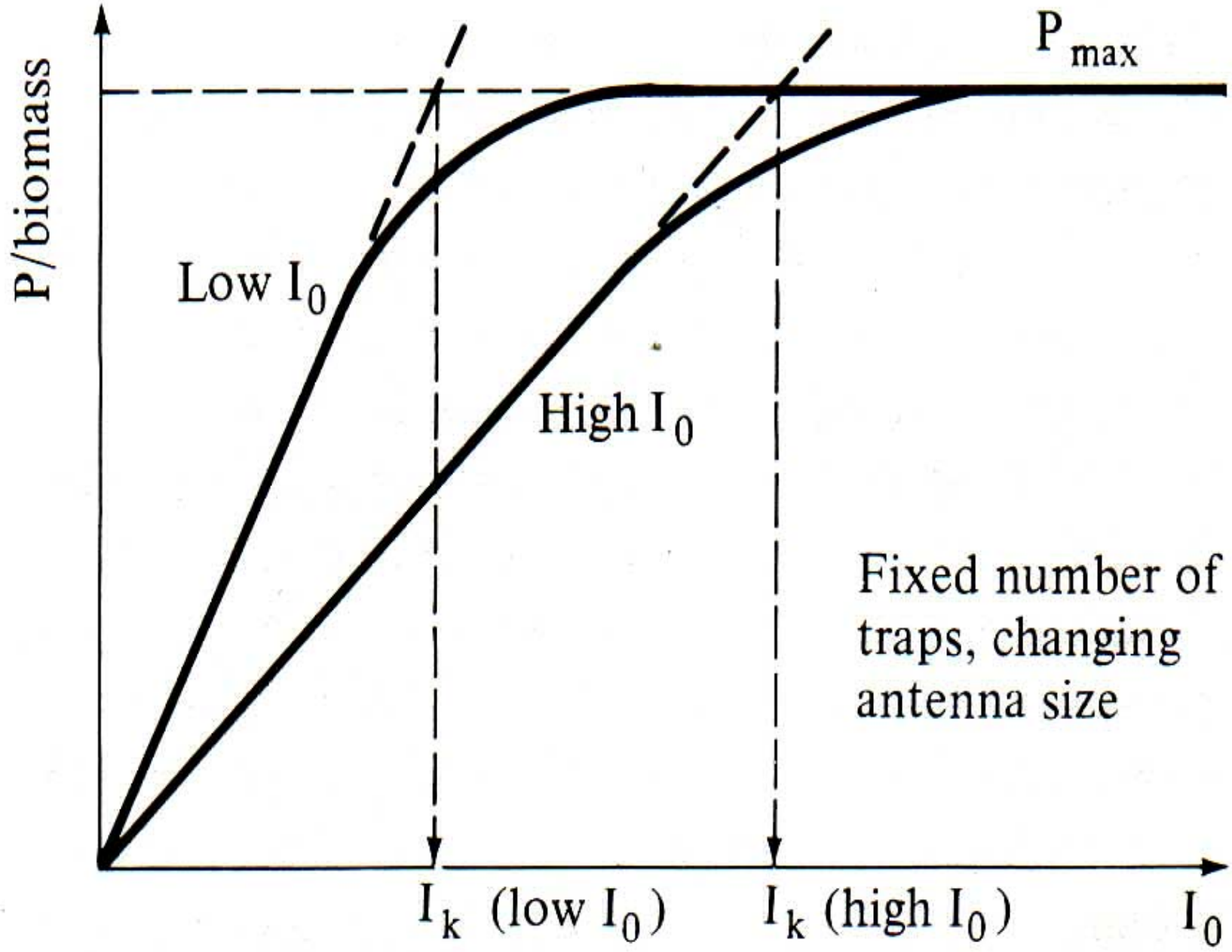
Not really-The photosynthetic apparatus in higher plants and alga is very much the same. The BIG advantage of micro-algae as compared to higher plant is the fact that we are making use of most of the biomass tatter then a specific part of the plant

How much light do we need in order to achieve maximal productivity?

Light – Is it too much of a good thing ?


Absorbed visible radiation (J m-2 s-1)
400
300
200
100
0
0
100
200
300
400
Visible radiation (J m-2 s-1)
Excess of absorbed energy
Photons used in photosynthesis


P
P/biomass
P max
Photoinhibition
Initial slope
P g
P n
Compensation
point
0
R
I k
I 0


P/biomass
P max
Low I0
High I0
Fixed number of traps, changing antenna size
Ik (low I0)
Ik (high I0)
I0

Solar radiation (1000kJ)

Outside phot thetically
ectrum

500

450

mical inefficiency

Carbohydrate synthesis

Photorespiration

Respiration

Biomass (5.1%)

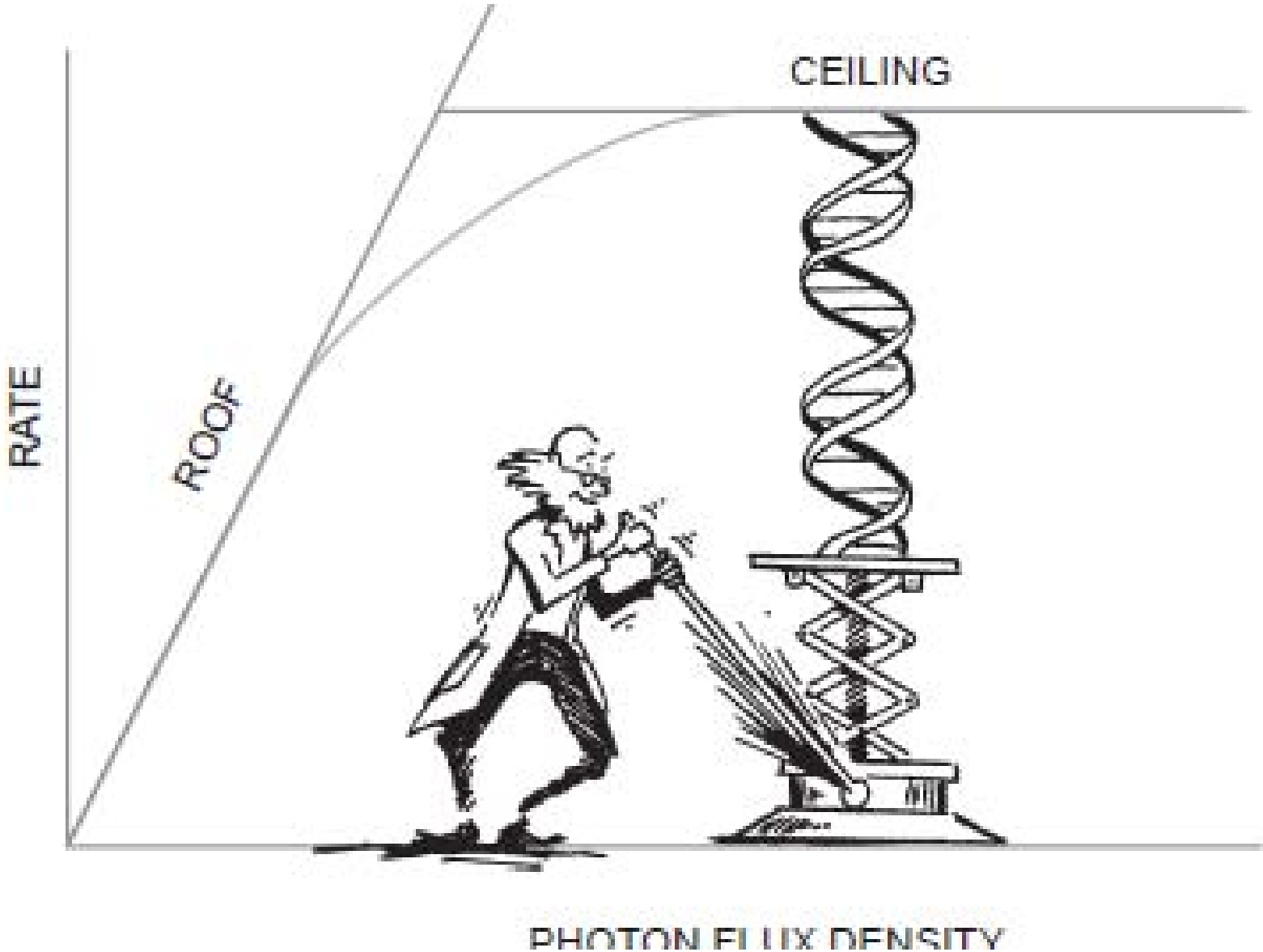
Potential $\varepsilon_c = 5.1\%$

Maximum observed $\varepsilon_c = 2.5\%$

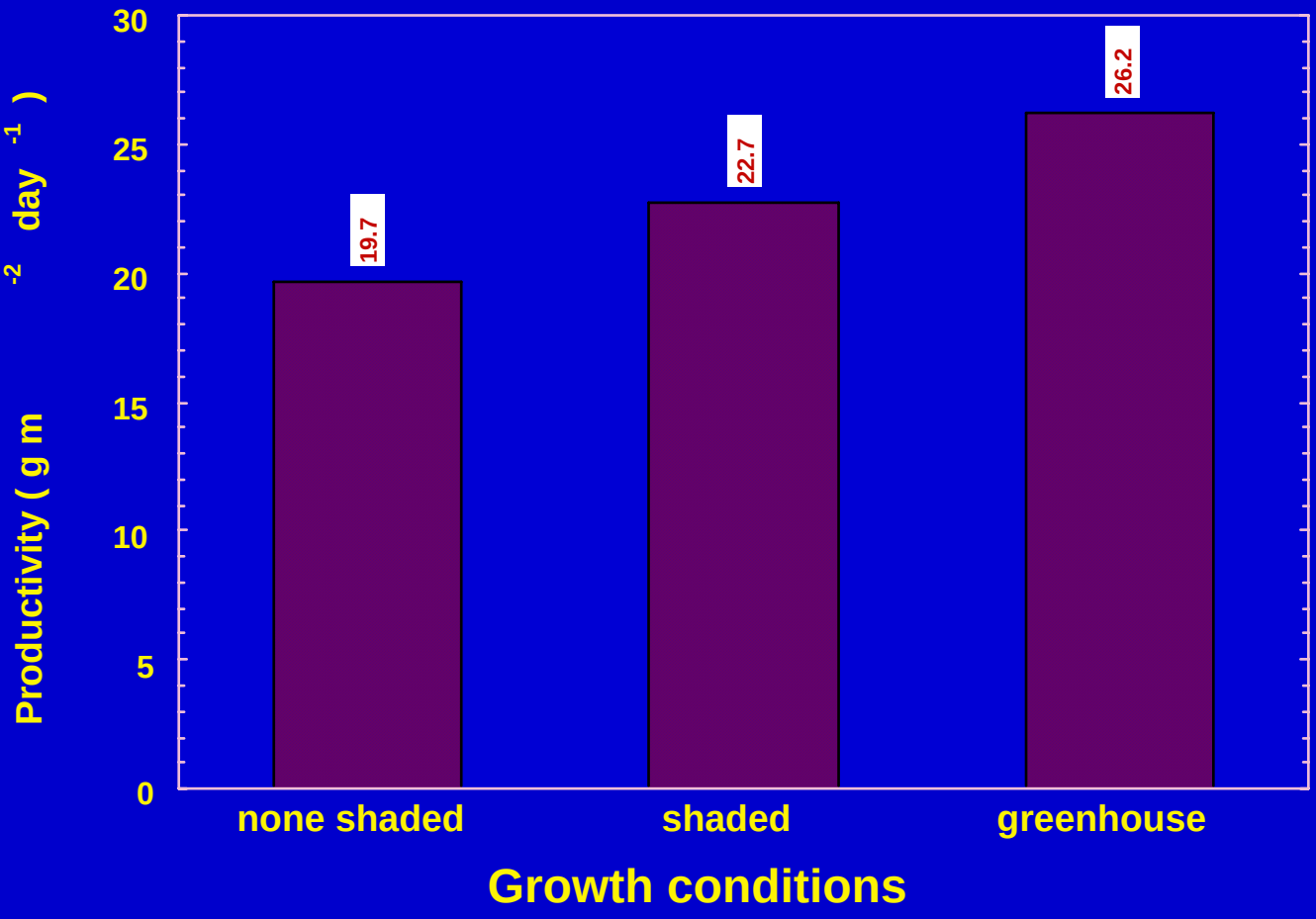
Average $\varepsilon_c = 0.1\%$

C4 lacks photorespiration 7.5%

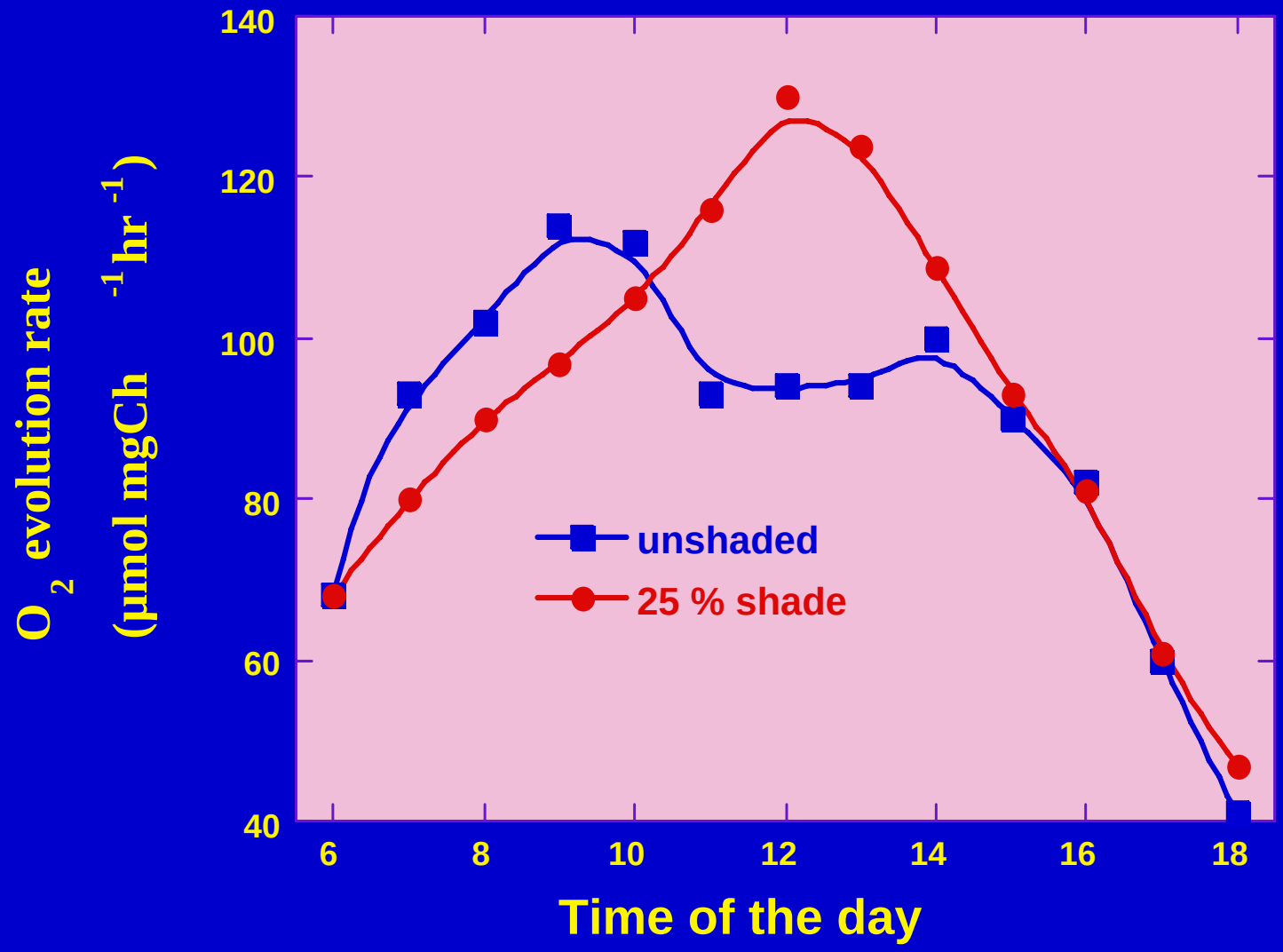
Efficiency of conversion of J sunlight into plant iomass (C3)


CEILING
RATE
ROOF
PHOTON FLUX DENSITY

Average daily productivity of *Spirulina* cultures grown outdoors at different growth conditions



Oxygen evolution rate in outdoor cultures of *Spirulina* grown under different light conditions

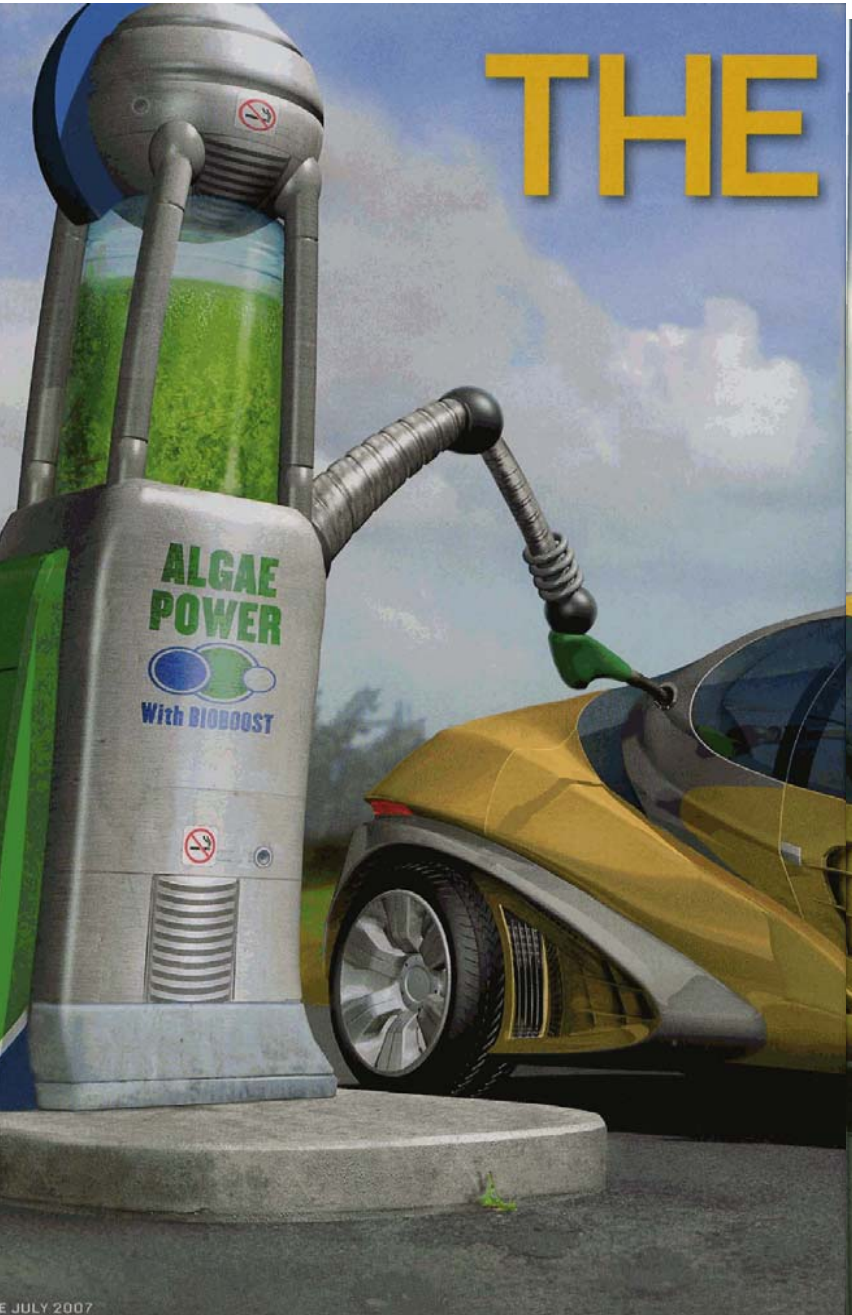



Can algae save the world?
...and other important questions about solving climate change

Stop dreaming and get back to work !

Just don’t do more of the same…?

Popular Science, July 2007



THE FUEL CELL

You're looking for a clean fuel that grows anywhere, needs only sunlight and water, and could produce enough oil to free the U.S. from its petroleum addiction? It's not ethanol you're after. Imagine converting oil from algae—yes, algae—into clean-burning biodiesel. Here's one start-up's plan to tu

BY ELIZABETH SVOBODA
ILLUSTRATION BY MATT STUBBINGTON

3 KEY FACTS

1. **Fats in algae can be made into biodiesel,** a renewable substitute for diesel fuel.
2. Researchers could grow enough algae to **power the entire U.S. transportation fleet** in any barren area a little bigger than New Mexico.
3. Algae farms set up next to power plants could **absorb carbon dioxide and convert it to oxygen.**

NEXT MONTH Find more green solutions in our Future of the Environment special issue.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Thank you